

Multi-Frame Dim Target Detection Using 3D Multiscale Geometric Analysis

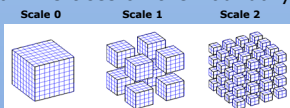
Efros Boris, Levi Ofer, Stanley Rotman

3D Beamlet Transform (Donoho and Levi)

Construction of 3D Beamlets

- 3D Beamlets is a strategic compact set of line segments
- The cardinality of the beamlet set is $O(n^4)$
- Every smooth path in the image can be approximated by a short chain of beamlets

1. Mark vertices on the Boundary of dyadic cubes



2. Connect marked vertex pairs in every dyadic cube



Beamlet Transform

Definitions:

Beamlet Transform: $T_l(b) = \int f(\gamma_b(l)) dl, b \in B_n$

Beamlet Coefficients: $\{T_l(b) : b \in B_n\}$

Beamlet Transform stands for the integral transform of the 3D image over the multiscale set (B_n)

Beamlet coefficient stands for the linear integral of the 3D image over the corresponding beamlet.

Beamlet-Based Graphs

Beamlet Graph:

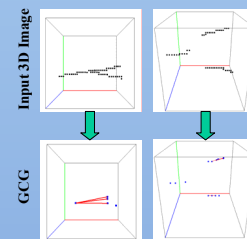
Vertices: Voxel corners

Edges: Beamlets

Good-Continuation Graph (GCG):

Vertices: Beamlets

Edges: Two beamlets connected by edge if they satisfy 'Good Continuation' relation.



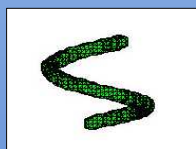
Notes:

Only beamlets with non-zero coefficients are used to construct GCG. Beamlet center of mass used for node location only for illustrative purposes.

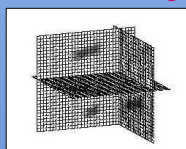
Beamlet-Based Algorithms

- First level algorithms** – mostly based on thresholding of beamlet coefficients.
- Second level algorithms** - based on the tree structure of dyadic cubes.
- Third level algorithms** - based on the neighboringness of beamlet coefficients according to the beamlet graph.

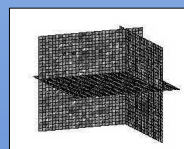
Illustrative example of a first level algorithm



3D original object hidden in noise



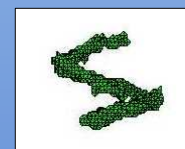
Noiseless image



Noisy image

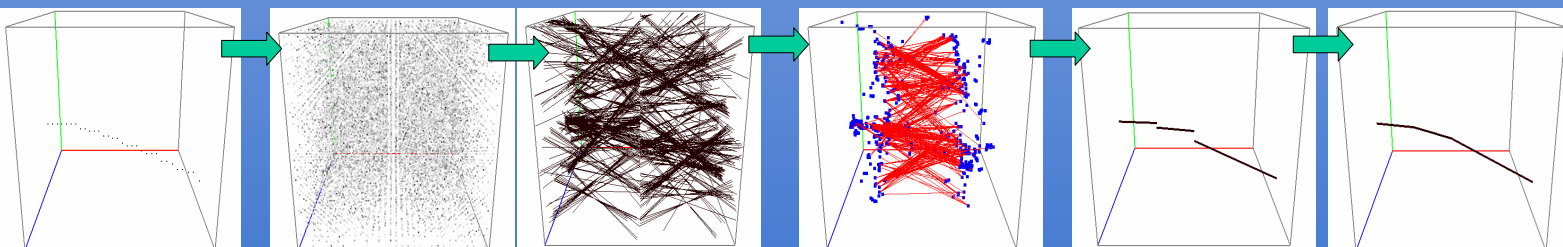


Simple beamlets threshold analysis of the image



Back Projection of the surviving coefficients

Multi-Frame Dim Target Detection in Synthetic Scenes



Noiseless image containing target trajectory

Noisy image containing target trajectory

Surviving Beamlets after thresholding and filtering

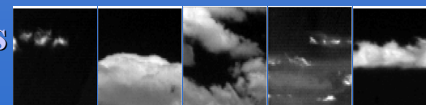
The corresponding Good-Continuation Graph

The set of Beamlets that define the "longest path" in the Good-Continuation Graph

The detected trajectory

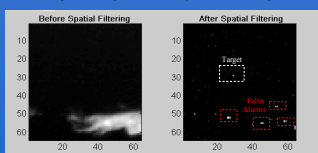
Structured Filter Operator

Multi-Frame Dim Target Detection in Real Scenes



False Alarms in Real Scenes

The reason: presence of global filamentary structures in complex scenes



Using back projection based whitening for successful detection in real scenes

General Description:

- 1) Find beamlet projections with high count of peaks.
- 2) Apply binary back-projection on the peak coefficients.
- 3) Use the result image as penalty function for the original image.
- 4) Apply MFD algorithm with the resulting image.

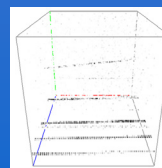
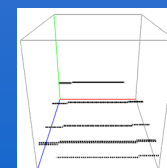
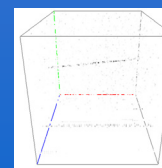


Image after spatial filtering



Binary back-projection for beamlet projection with number of peaks



Whitened image